Optimized Forecaster Farming: A New Tool to Put Accuracy into Precision Farming

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Abstract

Farmers looking at Precision Farming as a tool to better manage fields have found no real way to apply this technology to fertilization and crop production. The misconception between precision and optimization has lead many farmers to feel that the technology was oversold and not able to deliver more yield for less fertilizer dollars. Farmers required a tool to optimize the dollars spent on fertilizer to achieve the highest Net Return per acre. The PRS™ Forecaster is a constrained-resource computer model that can forecast the yield potential and fertilizer response site by site through a field. The model was allowed to distribute $2160.00 of fertilizer N, P, and K across 54 acres in a way that optimized the whole field net return. This was compared to a control site where the same $40.00/acre was spent but on a best "average" blend of fertilizer. Field validation of this optimization proved that more net return ($19.50/acre) could be derived with reallocation of fertilizer dollars using the PRS™ Nutrient Forecaster.

Introduction

Early papers on precision farming suggested that the main potential for western Canada would be in variable rate fertilization and variable spraying technology (Roberts, 1996). The utility of the GPS and yield mapping tools to describe "where it is" and "what it yields" has been readily recognized by both farmers and machinery manufactures. However, even this application was often oversold since a farmer could not adequately plan "what to do" from a map indicating "what was".

More recently, reports have surfaced suggesting that precision farming is a "dead horse" (Mangold, 2000) or failed to take off (MacArthur, 2001). These articles reinforce the notion that farmers simply have inadequate tools to decide if the intensive management of fertilizer pays. Put another way, farmers know that the equipment exists to get them to the same spot in the field and put on the same amounts of fertilizer with exacting precision but, what about the accuracy of that decision. Was this an accurate rate of fertilizer considering all of the factors that control yield? In essence farmers are asking for an optimization of the fertilizer dollars on each site within the landscape they farm in order to obtain the highest net return on the field as a whole.

The PRS™ Nutrient Forecaster is a constrained-resource mechanistic model that allows farmers the flexibility to set site-specific factors that constrain yield (Greer, 2002). This paper will discuss a farm scale case study where barley was grown to compare an optimized versus field average PRS™ Forecast of fertilizer required.

Methodology

The field site was located on the NW 01-07-20 W2. The soil type was mapped as an Amulet/Brooking complex. The relief on the site was significant as the Missouri Coteau begins to rise on this quarter section. Topography was logged using the Flexi-coil task controller attached to a John Deere Starfire receiver with WAAS correction. Figure 1 shows the relative sampling sites and field boundaries overlaid on the topography.

Three fields were separated for the experiment. Field 1 was not included in the study since the site was underseeded to sweet clover and could not be sprayed for volunteer canola. Field 2 was 54 acres in size and was selected as the site for optimization of net return using the PRS™ Nutrient Forecaster. Field 3 comprised 18 acres and was used as the average fertilized control.

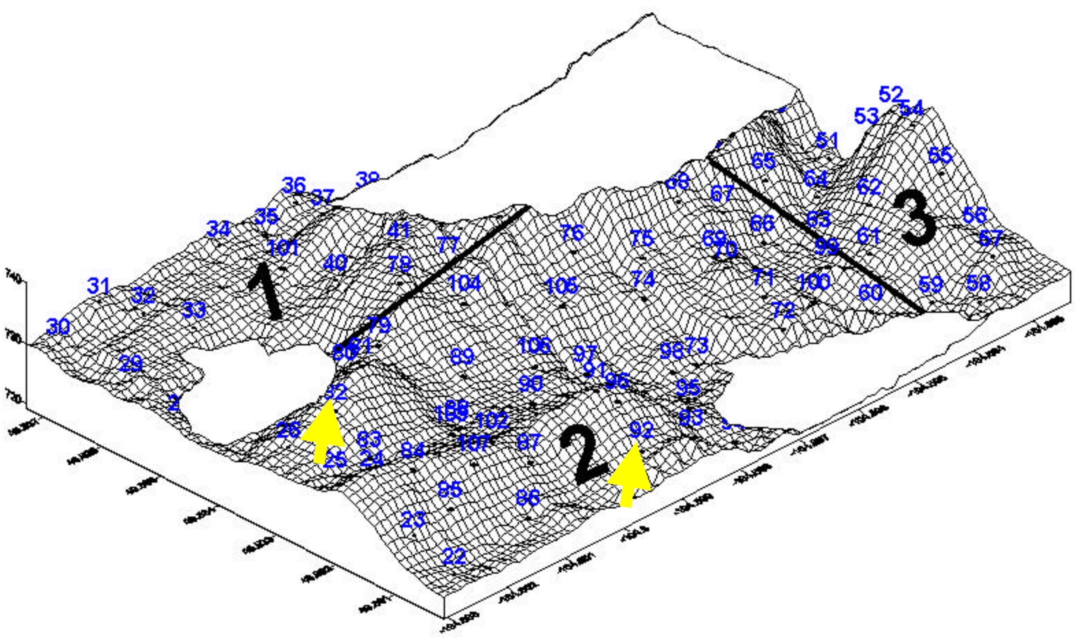

Figure 1. Topography and sample points where soil data was collected using the PRS™ technology. Yellow arrows denote sites 82 and 92.

In the fall of 2001, eighty-six (86) soil samples were taken in a "smart" or directed sampling scheme. This involved sampling equivalent number of upper level, mid-slope and lower-level positions in a balanced manner, thus allowing meaningful interpolation across the site. Field 2 had 46 sample sites that were analyzed for PRS™ nutrient supply rate, texture and stored water. Field 3 contained 23 sampling sites.

Water Redistribution

Using the topography and slope percentage, a simple water budget was calculated to spatially proportion the 8 inches of growing season precipitation in our "what if" scenario. Yield forecasts and nutrient responses are greatly influenced by the Total Available water. Hence upper-slopes having a steep gradient are likely to be less responsive to fertilizer simply due to a limitation in water infiltration and storage. Field 2 water settings ranged from a low of 5.10 inches at site 82, to a high of 9.71 inches at site 92 (Figure 1).

Optimization

The PRS^{TM} Nutrient Forecaster model was initialized with the soil nutrient supplies, soil texture and water redistribution data for each of the 46 sites in Field 2. The model was then constrained to spend $40/ac for a total of $2160.00 on Field 2. Allocation was allowed based on the N, P or K response curve at each location. The N, P and K nutrient prices were set at $0.41/lb, $0.35/lb, $0.15/lb, respectively. The Barley produced was given a value of $2.00/bu. The allocation of these resources was free to flow from site to site within Field 2 until a maximum Net Return after fertilizer was found. Fertilizer applications ranged from 0 to 85 lb/ac actual N. Phosphorus and potassium rates ranged from0 to 48 lb/ac and 0 to 78 lb/ac, respectively.

The same constrained-resource model was then used to develop an average best blend for Field 3. Nutrient supply rates, texture and water inputs were averaged across the 23 sample locations. The optimum return for $40/ac of inputs (total of $720) was calculated using the same nutrient price inputs. Figures 2-4 show the actual rates of products applied on the site using the Flexi-coil 50 series Task controller.

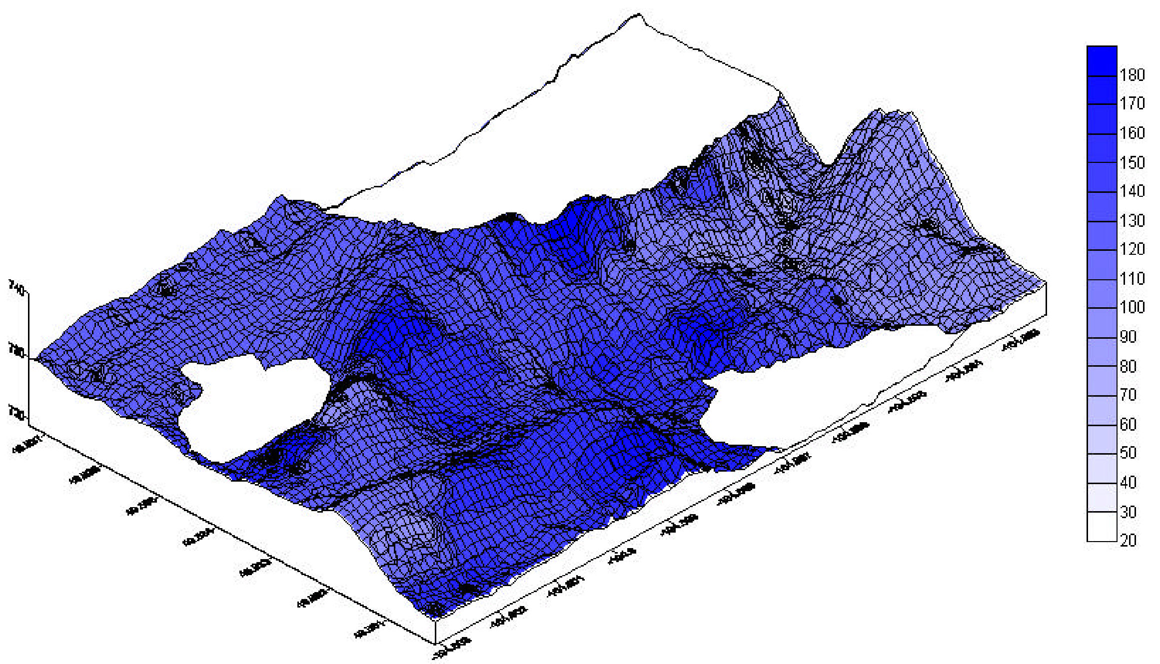

Figure 2. Applied rates of 46-0-0 in lbs product per acre overlaid on topography.

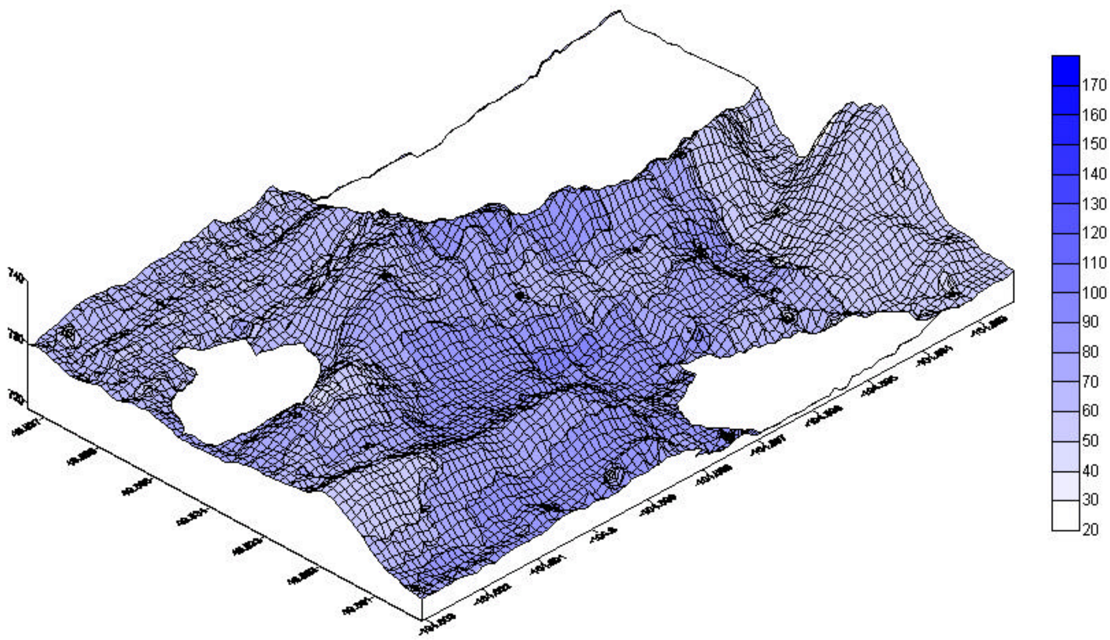

Figure 3. Applied rates of 11-51 -0 in lbs product per acre overlaid on topography.

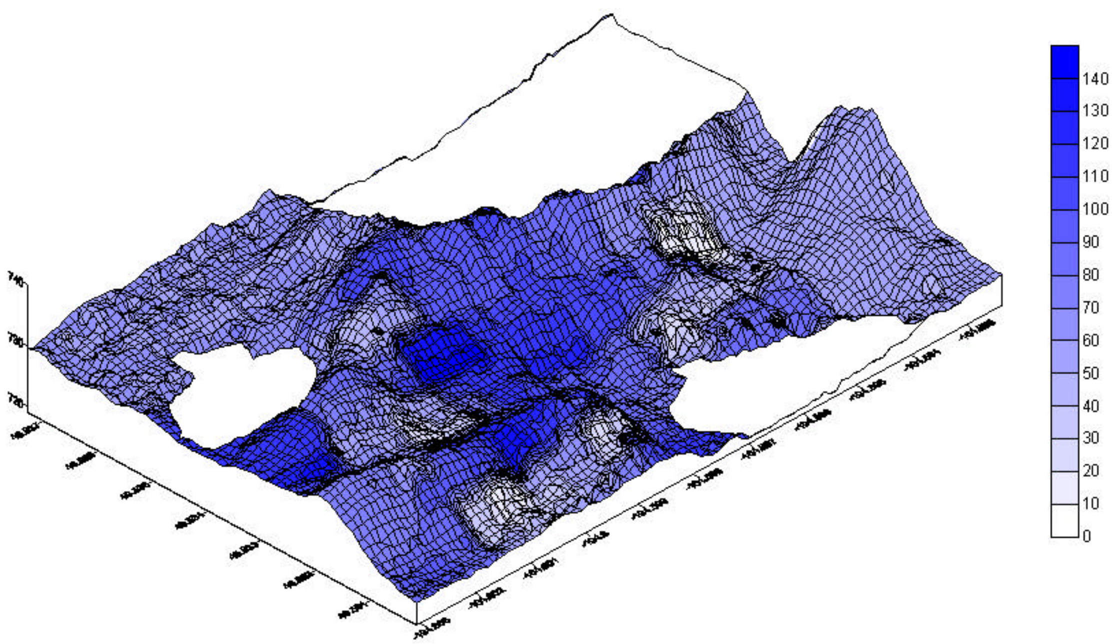

Figure 4. Applied rates of 0-0 -62 in lbs product per acre overlaid on topography.

Results

The growing season precipitation set in the "what if" scenario was 8 inches. Actual growing season precipitation on the site was 3.5 inches. The stored water present after the winter period was estimated at 2 to 3 inches. Running the same water redistribution assumptions resulted in total water ranging from 4.0 to 6.8 inches of water. Maximum barley yields Forecast with the original 8 inch "what if" scenario ranged from 63 to 115 bu/ac. Maximum yields Forecast using the observed precipitation and soil moisture settings were calculated to be between 30 to 80 bu/ac. Actual yield range on the field was 20 to 80 bu/ac (Figure5).

Field 2 average yield was 48 bu/ac (Figure 5). The yield map indicated that upslope positions experienced limited yield (25-35 bu/ac). This was expected since both water and nutrients were limited. Low slope regions that had higher total water available, yielded well above the average (60-70 bu/ac). The histogram of yield showed that 16.3 of the 54 acres was found to yield in the 50-59 bu/ac yield class. Only 9.8 acres are in the yield classes less than 39 bu/ac (Figure 6).

Conversely, on the control field (Field 3), only 1.5 of the 18 acres were in the greater than 50 bu/ac class and nearly 50% of the acres yielded less than 39 bu/ac (Figure 6). This data indicates that the low slope positions in the control field did not produce to the same yield potential because the fertilizer blend applied was the average considering upslopes, midslopes, and lowslopes. This increasing of yield on the midslopes at the expense of the lowslopes was the main factor in causing the reduced average yield (42 bu/ac) on the control field.

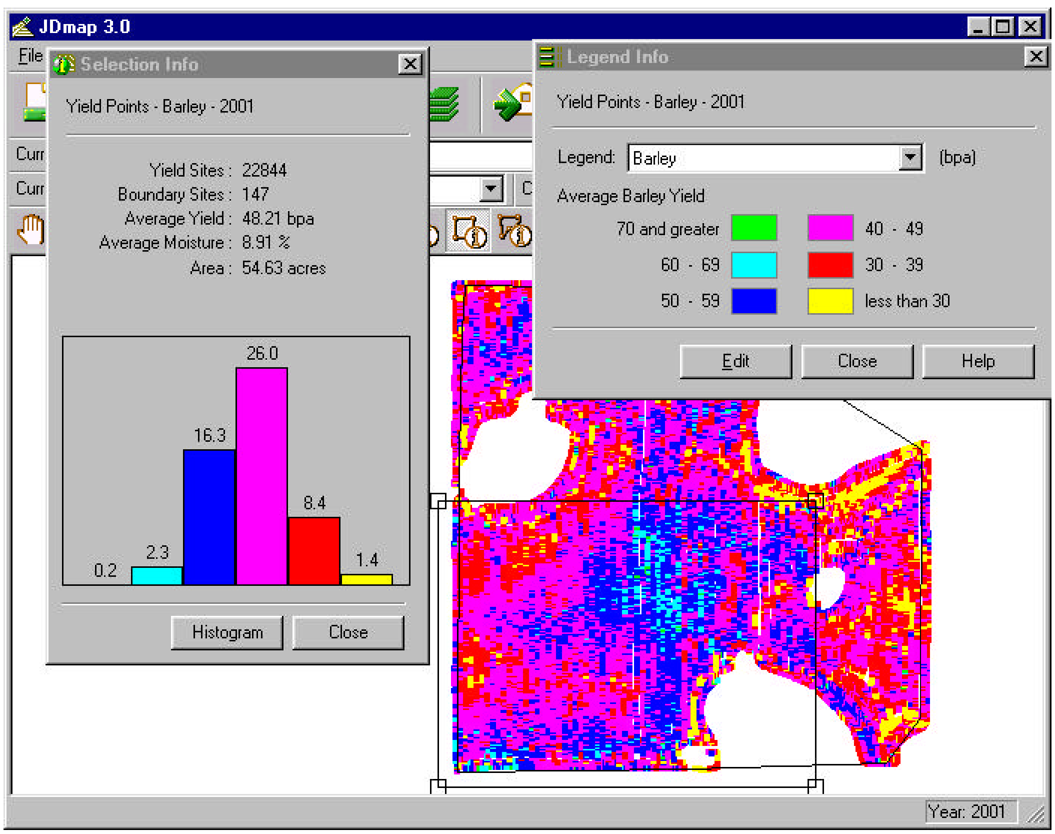

Figure 5. Yield map on field 2 showing acres within each yield class.

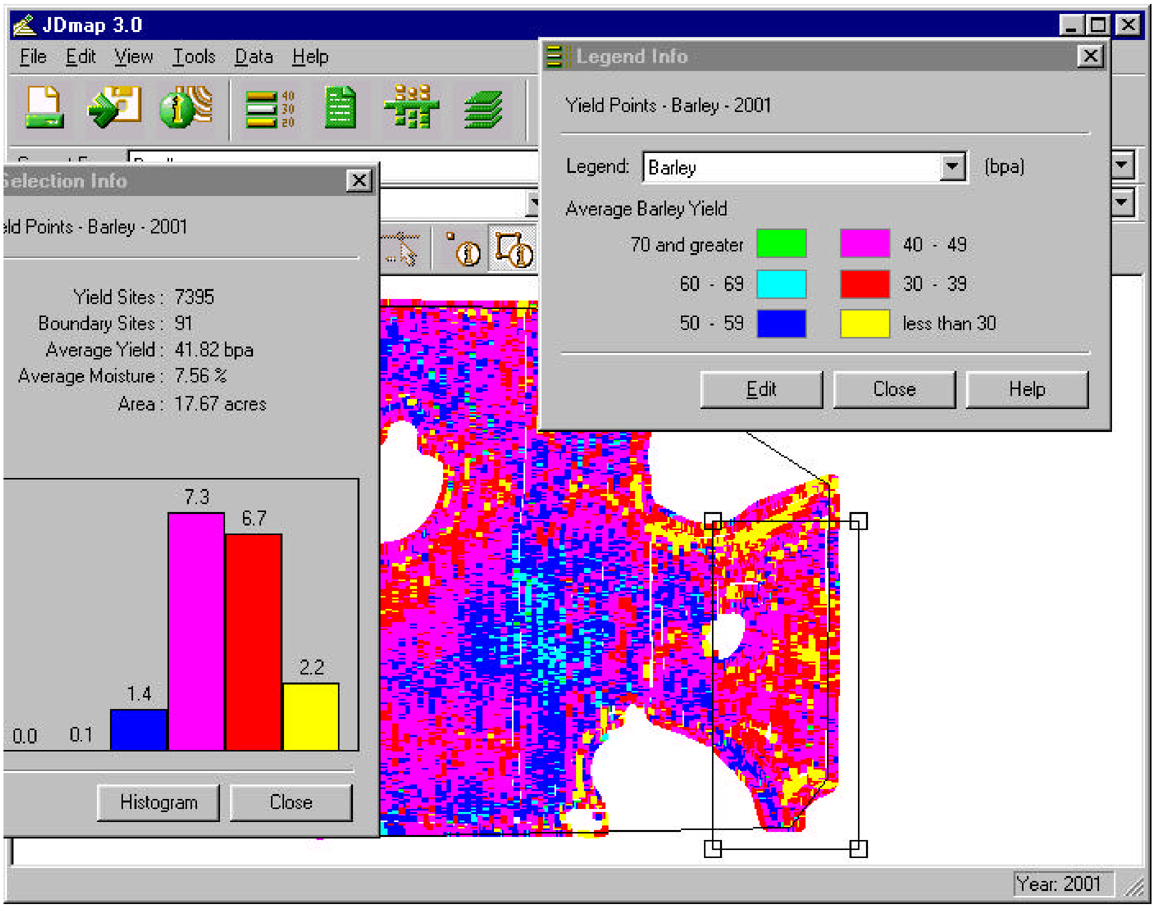

Figure 6. Yield map on field 3 showing acres within each yield class.

Conclusions

Optimization is the true goal of farmers when considering variable fertilization. The net return to the total dollars spent on fertilizer for the entire field should be optimized. This implies that the sites with poor response to fertilizer due to unfavorable soil conditions will receive little amendment if fertilizer dollars are limited.

Utilizing the PRS™ Nutrient Forecaster, the site-specific water regime, soil texture, soil density and soil salinity can be adjusted to calculate a maximum yield potential. Optimizing each site involves using the specific response curves that are dynamically scaled for that site considering both soil supply and plant demand. Each dollar of fertilizer is then passed around from site to site in the model until the marginal return on the whole field is highest, given the constraint of fertilizer dollars spent.

Considering a year with 8 inches of growing season precipitation and an average of $40.00/ac spent on fertilizer, optimizations for Field 2 indicated a redistribution of fertilizer dollars to low slope positions. Despite drier than Forecast conditions, a net yield advantage was observed on the completely optimized site. The value of which equals $19.50/ac.

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